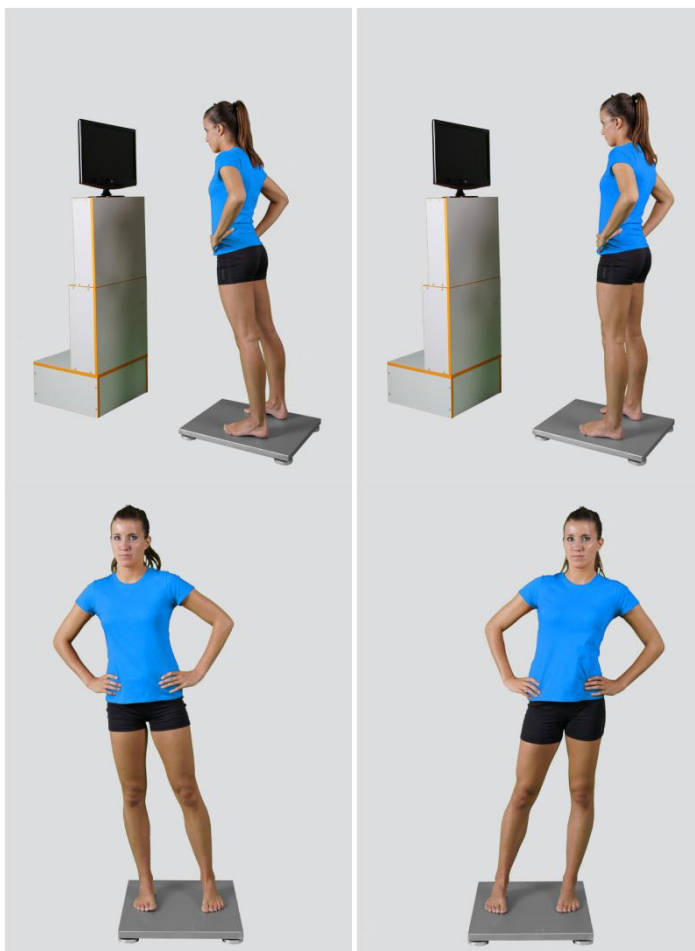# MODULE: LIMITS OF STABILITY

BRIEF DESCRIPTION:

Different from the quiet stance, every day functional situations often require more demanding dynamic balance situations and corresponding balance control. A typical example are those motor tasks in which a subject has to voluntarily shift the body`s centre-of-gravity above the support area. Such leaning of the body in different directions will result in an evident centre-of-pressure (COP) displacement. Maximal range of voluntary body leaning in different directions can be assessed by measuring the COP displacements. Stability limits can be defined as the extent to which an individual is willing to lean his/her body in a certain direction. One commonly used clinical measure of stability limits is the functional reach test. However, it has been shown that the results of this test and those of the maximal COP displacement test do not correlate as expected. We can say that the COP based limits of stability is proposed as the current golden standard for the evaluation of this specific type of voluntary dynamic balance control.

Evaluation of limits of stability gives us the information about the volitional balance control of the centre-of-gravity and can be quantitatively evaluated using force plate measurements. We can ask a subject to perform voluntary body leaning task in different directions thereby initiating the movement as quickly as possible following the visual start signal. Such a measurement set-up will enable us to identify direction specific weak points of the subject`s balance and to gather additional information about the other functionally specific abilities regarding balance. The latter encompass situational reaction times in the context of standing posture, start velocity of the voluntary COP shift, etc.

When the Limits of Stability module opens, the existing measurements of the selected subject inside the current Visit are displayed and the user can review them (see section Analysis for details). If no measurements have yet been done for this subject, than only the option to start a new measurement is enabled. In order to begin a new measurement, click New Measurement button and select the Input Parameters to exactly define the measurement task.

When the New Measurement button is selected for the first time after entering the Limits of Stability module, the force plate is initialized. After the automatic initialization process is finished, the zero offset must be done (follow the instructions on the pop-up message). The plate must be unloaded during the entire initialization and zero offset procedure. This procedure is performed every time you enter the Limits of Stability measurement module. Zero offset can be repeated any time manually by pressing the Offset button, otherwise the automatic zero offset is done every 30 minutes.

BASIC FUNCTIONS:
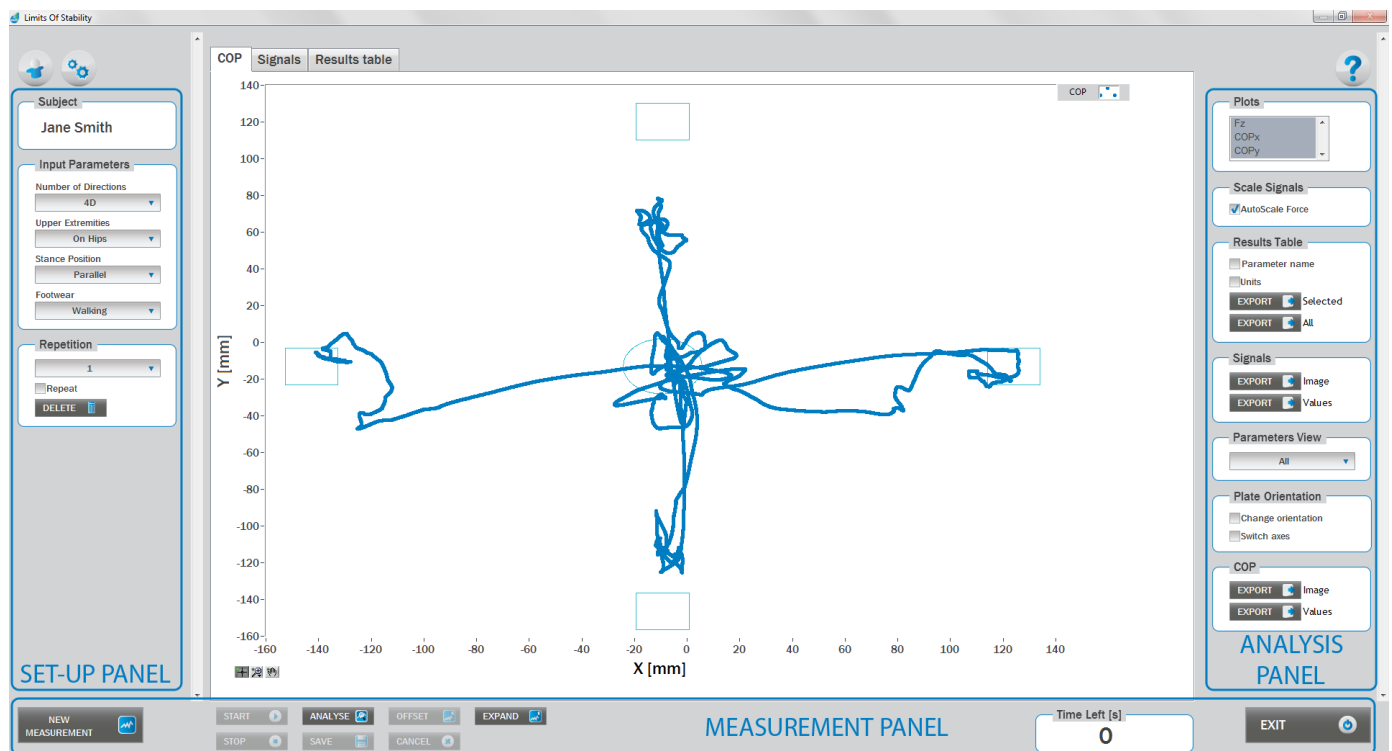
SET-UP PANEL:

SUBJECT

Name
The selected subject.

INPUT PARAMETERS

See Selecting Input Parameters section for details.

REPETITION

Repetition
Number of repetitions for the selected Input parameters.

Repeat
If checked, the selected repetition is replaced when the new measurement is performed.

Delete
Delete the selected repetition.

ANALYSIS PANEL:

PLOTS

Plots
The list of all channels. The selected channels are shown on the graph.

SCALE

AutoScale Force
If checked, the vertical scale of the graph is adapted to the maximum and minimum value of all force signals.

RESULTS TABLE

In the Result Table panel, result parameters from Result table tab can be exported into clipboard, CSV or TXT format. Format of the file can be set in settings window under export section. For details about setting the parameters refer to Settings Section.

Parameter Name
Parameter name will be included.

Units
Units of the parameters will be included.

Export Selected
By clicking on Export Selected button only the parameters that are selected in the table will be included.

Export All
By clicking on Export All button all parameters from the table will be included.

SIGNALS

In the Signals panel, image or values (row data) of acquired signal can be exported. Image and values can be exported with different parameters, which can be set in Settings window under export section. For details about setting the parameters refer to Settings Section.

Export Image

Export the image of signals (as visible on the graph on the Signals tab)into the clipboard. Image can be paste in any image editor.

Export Values

Export values (raw data) of signals (as visible on the graph on the Signals tab) into CSV or TXT format. Format of the file can be set in settings window under export section. For details about setting the parameters refer to Settings Section.

PARAMETERS VIEW

In the Parameters View panel, calculated parameters which are displayed in the result table can be set. By default, all and basic view are available. Basic view contains preset parameters and cannot be changed. Custom view can be defined, by clicking »Manage…« button.

To create a new view click on add button and enter the name of the view. Parameters included in the view are selected by checking the checkboxes next to them. To confirm the changes click save.

COP

In the COP panel, image or values (row data) of acquired signal can be exported. Image and values can be exported with different parameters, which can be set in Settings window under export section. For details about setting the parameters refer to Settings Section.

Export Image

Export the image of signals (as visible on the graph on the Signals tab)into the clipboard. Image can be paste in any image editor.

Export Values

Export values (raw data) of signals (as visible on the graph on the Signals tab) into CSV or TXT format. Format of the file can be set in settings window under export section. For details about setting the parameters refer to Settings Section.

PLATE ORIENTATION

Change orientation

Plate orientation is changed for 180°.

Switch axes

Switches the X and Y axes without moving the force platform.

MEASUREMENT PANEL

New Measurement

Starts with a new measurement.

Start

Starts the measurement.

Stop
Stops the measurement.

Save
Saves the measurement.

Cancel
Cancel the last measurement.

Offset
Makes zero offset. Note that the force platform must be unloaded during the process.

Analyse
Performs the analysis.

Collapse
Collapses the graph and the side panels are shown.

Expand
Expands the graph and the side panels are hidden.

Time left [s]
Time left to the end of measurement.

Exit
Closes the measurement module.

SELECTING INPUT PARAMETERS:

Before the measurement can start, the user has to choose some input parameters with which the measured motor task (i.e. quiet stance task) is specifically defined. These parameters are important for further analysis, comparisons and reporting. The characteristics of the voluntary body leaning task are defined by the following parameters:
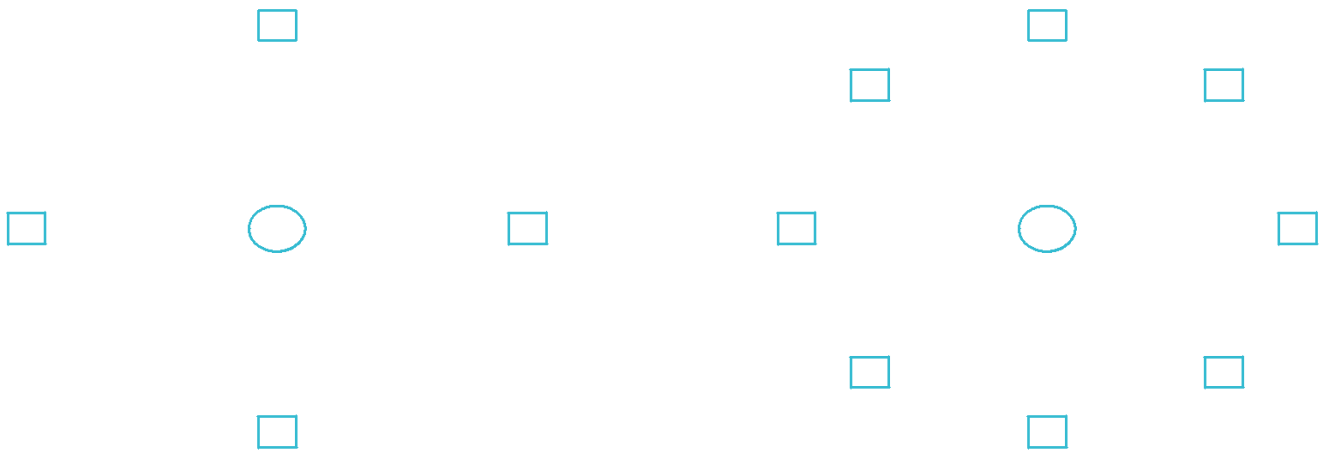
NUMBER OF DIRECTION:

4D - Four Directions
Forward, backward, right, left.

8D - Eight Directions
Forward, backward, right, left, forward-right, backward-left, backward-right, forward-left.

UPPER EXTREMITIES:

On Hips

The subject places his/her hands on his/her hips.

Free

Subjects are free to use their arms as they want. In case of the easy balance tasks the hands will normally remain passively hanging. However, in more demanding tasks the free use of the hands can be of great help.

Other user defined

In the Settings panel of the main window of the software the user can define any other position of the upper extremities (see Settings Section for details). After doing so, the newly defined input parameter will from then on appear as an optional choice under the Upper Extremities in the Body Sway measurement module.
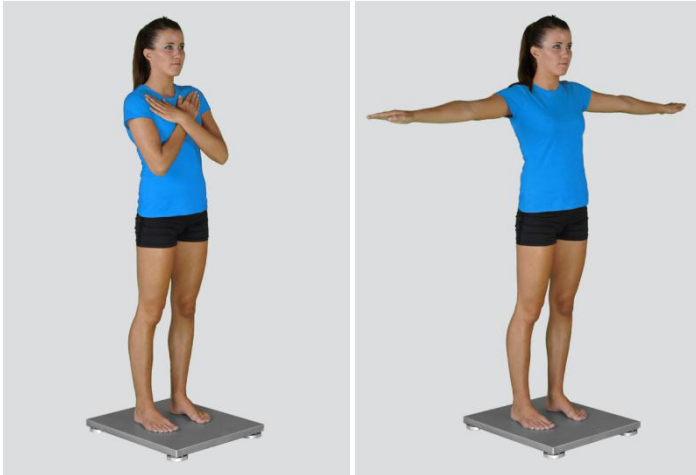
STANCE POSITION:

Parallel Stance

The subject is standing in the centre of the force plate with the feet placed parallel at the shoulder width. The feet are oriented in anterior-posterior direction (along the Y-axis of the force plate) with the toes pointing anteriorly (+Y). Throughout the measurement the subject sustains his/her normal upright stance position.

Semi-Tandem Stance

The subject is stance in the centre of the force plate with the feet placed close together and shifted longitudinally against each other for one half of the length of the foot (i.e. semi-tandem foot position). The feet are oriented in anterior-posterior direction (along the Y-axis of the force plate) with the toes pointing anteriorly (+Y). Throughout the measurement the subject sustains his/her normal upright stance position. Semi-tandem stance with the dominant leg in front is predominantly used; the opposite foot position is sometimes also referred as "contra semi-tandem".

Tandem Stance

The subject is standing in the centre of the force plate with the feet placed in-line one behind the other (i.e. heel-to-toe or tandem feet position). The feet are oriented in anterior-posterior direction (along the Y-axis of the force plate) with the toes pointing anteriorly (+Y). Throughout the measurement the subject sustains his/her normal upright standing position. Tandem stance with the dominant leg in front is predominantly used; the opposite foot position is sometimes also referred as "contra tandem".


Single Leg Stance – Left / Single Leg Stance – Right

The subject is standing on one leg in the centre of the force plate. The foot is oriented in anterior-posterior direction (along the Y-axis of the force plate) with the toes pointing anteriorly (+Y). Throughout the measurement the subject sustains his/her normal upright standing position.

Other user defined

In the Settings panel of the main window of the software the user can define any other type of stance (see Settings Section for details). After doing so, the newly defined input parameter will from then on appear as an optional choice under the Stance Position in the Body Sway measurement module.
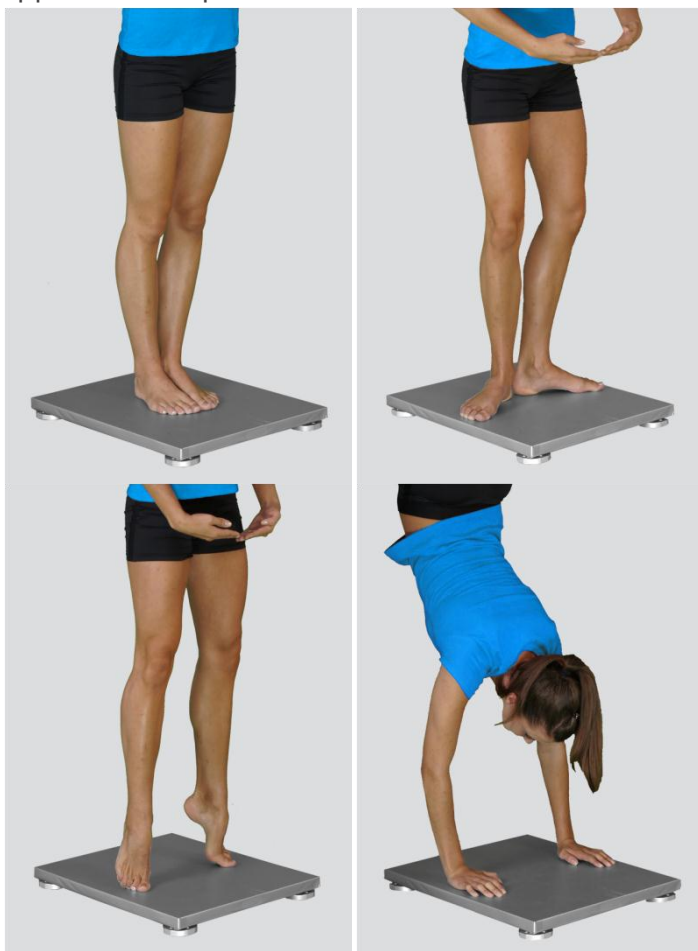
FOOTWEAR:

Barefoot/Running Shoes/Walking Shoes/High Heels

The user selects the type of the shoes that the subject is wearing.

Other user defined

In the Settings panel of the main window of the software the user can define any other type of footwear (see Settings Section for details). After doing so, the newly defined input parameter will from then on appear as an optional choice under the Footwear in the Limits of Stability measurement module.

MEASUREMENT:

After selecting the input parameters, the subject steps on the force plate and acquires the required position in a way that the orientation of the body is consistent with that of the plate (i.e. +Y direction of the plate is the anterior direction). After you are satisfied with the quiet stance of the subject, click Start. After this the software begins with the signal acquisition and the time left until the end of the test is displayed in the top-left corner of the screen. For details about this automatic acquisition please see Settings Section.

If you want to start a new measurement, click the New Measurement button and repeat the procedure. Before doing so, you can change the Input Parameters; if not, the Input Parameters of the previous measurements will be used. If you want to repeat a certain measurement, click on the drop down menu, select the repetition you want to replace and check the box Repeat. Then click Start and a pop-up window will ask you if you really want to repeat the measurement. Click OK if you want to repeat.

ANALYSIS:

Analysis enables you to check the signals of the ground reaction force (GRF) and the calculated parameters. Under the COP tab you can see the X:Y signal. Individual components of the ground reaction forces and of the COP movement can be visualized under the Signal tab. Under the Results Table tab you can see all the calculated parameters numerically, while the visualisation of the results comparisons can be done under the Results Graphs tab. These two tabs enable you to make quick comparisons of the values of the parameters among different repetitions and/or among different sub-versions of the body sway test. If you want to confirm the measurement, click Save. If you would like to export the calculated parameters use Export function in Result Table panel.
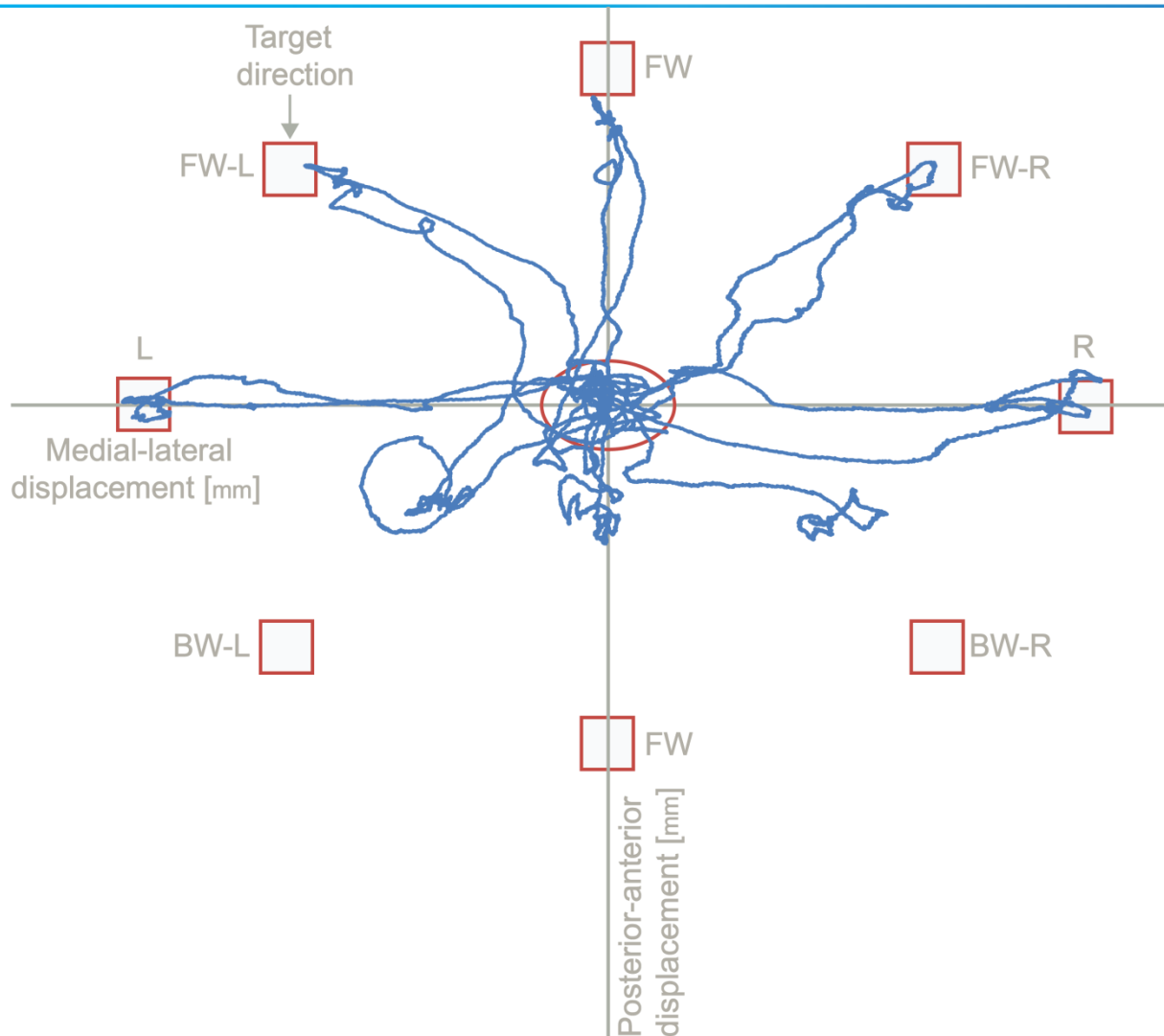
CALCULATED PARAMETERS:

GLOBAL

NOTE: All parameters are calculated in the following directions:
- Forward
- Backward
- Right
- Left
- Forward – Right
- Backward – Left
- Forward – Left
- Backward - Right

Reaction T [s]
Is the time in seconds between the command to move and the patient's first movement.

Movement V [mm/s]
Is the average velocity of the COP movement in millimeters per second.

Maximum Excursion [mm]
Is the maximum distance achieved during the trial.

Direction Control [°]
Is a comparison of the amount of movement in the intended direction (towards the target) to the amount of movement in the non-intended direction (away from the target).

Maximal body lean [°]
It is a maximal incline of the body in relation to the starting position expressed in degrees.

REFERENCES:

Baratto, L., Morasso, P. G., Re, C., & Spada, G. (2002). A new look at posturographic analysis in the clinical context: sway-density versus other parameterization techniques. Motor Control, 6(3), 246-270.

Belaire-Franch, J., Contreras, D., & Tordera-Lledo, L. (2002). Assessing nonlinear structures in real exchange rates using recurrence plot strategies. Physica D: Nonlinear Phenomena, 171(4), 249-264.

Borg, F. G., & Laxaback, G. (2010). Entropy of balance--some recent results. Journal of Neuroengineering and Rehabilitation, 7, 38.

Collins, J. J., & De Luca, C. J. (1993). Open-loop and closed-loop control of posture: a random-walk analysis of center-of-pressure trajectories. Experimental Brain Research. Experimentelle Hirnforschung. Expérimentation Cérébrale, 95(2), 308-318.

Collins, J. J., & De Luca, C. J. (1995). The effects of visual input on open-loop and closed-loop postural control mechanisms. Experimental Brain Research. Experimentelle Hirnforschung. Expérimentation Cérébrale, 103(1), 151-163.

Collins, J. J., De Luca, C. J., Burrows, A., & Lipsitz, L. A. (1995). Age-related changes in open-loop and closed-loop postural control mechanisms. Experimental Brain Research. Experimentelle Hirnforschung. Expérimentation Cérébrale, 104(3), 480-492.

Jacono, M., Casadio, M., Morasso, P. G., & Sanguineti, V. (2004). The sway-density curve and the underlying postural stabilization process. Motor Control, 8(3), 292-311.

Morasso, P. G., & Schieppati, M. (1999). Can muscle stiffness alone stabilize upright standing? Journal of neurophysiology, 82(3), 1622.

Richman, J. S., & Moorman, J. R. (2000). Physiological time-series analysis using approximate entropy and sample entropy. American Journal of Physiology. Heart and Circulatory Physiology, 278(6), H2039-2049.

Riley, M. A., Balasubramaniam, R., & Turvey, M. T. (1999). Recurrence quantification analysis of postural fluctuations. Gait & Posture, 9(1), 65-78.

Webber, C. L., & Zbilut, J. P. (1994). Dynamical assessment of physiological systems and states using recurrence plot strategies. Journal of Applied Physiology (Bethesda, Md.: 1985), 76(2), 965-973.